



**Physics 396 - Topics: General Relativity
Spring 2019**

Professor: Dr. Chad Middleton

Classroom	Wubben Hall 366
Class Hours	1-1:50 MON, WED, & FRI
Office	Wubben Hall 228A
Office Hours	2-3:00 MON & WED, 11-12:00 TUE & FRI, 9-10:00 THU
Office Phone	970-248-1173
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Required Text:

Gravity: An Introduction to Einstein's General Relativity by James B. Hartle, Addison Wesley (ISBN 0-8053-8662-9)

Course Description:

"Einstein's relativistic theory of gravitation – general relativity – will shortly be a century old. At its core is one of the most beautiful and revolutionary conceptions of modern science – the idea that gravity is the geometry of four-dimensional spacetime. Together with quantum theory, general relativity is one of the two most profound developments of twentieth-century physics."

- *Gravity: An Introduction to Einstein's General Relativity*

This course will be an introduction to Einstein's theory of general relativity. We will begin by reviewing Newtonian gravitation and Einstein's theory of special relativity. Then, after developing the tools for describing curved spacetimes, we will explore the simplest physically relevant solutions of the Einstein field equations - spherically symmetric stars, static black holes, FRW cosmologies, and wormholes.

“When forced to summarize the general theory of relativity in one sentence; time and space and gravity have no separate existence from matter.”

-- Albert Einstein

Course Expectations:

An undergraduate student should expect to spend on this course a *minimum* of two hours outside the classroom for every hour in the classroom. The outside hours may vary depending on the number of credit hours or type of course. More details are available from the faculty member or department office and in CMU's *Curriculum Policies and Procedures Manual*.

General Relativity (GR) is inherently mathematical by its very nature. A true understanding of GR will be realized *only* after you, the student, actually *do* GR (i.e. homework and exam problems). You should treat every homework problem as a test of your understanding of the subject material. The homework sets will be quite long and will require many hours of work. It will not be unusual for you to spend six hours or more on a homework set. Hard work will be

demanding from you in this course!

Course Requirements:

Assignments:

- There will be roughly one assignment per week consisting of approximately 4-7 homework problems per assignment. Assignments are to be turned in by 5 pm on the date due. Late assignments will be penalized by a 10% grade reduction each day they are late.
- You are encouraged to discuss homework problems with your classmates. Working problems with your peers can be an excellent learning method, however, anything turned in must be your own work.

Examinations:

- There will be four exams during the semester and a *cumulative* final. Each exam will consist of an in-class section and/or a take-home section.

Grading:

Your grade for this course is based on the following activities, weighted as shown

<i>Homework Assignments</i>	<i>20%</i>
<i>Exams (4)</i>	<i>60%</i>
<i>Final Exam</i>	<i>20%</i>

Grading Scale:

- All graded work will be assigned a numerical score. You may estimate the corresponding letter grade by computing a percentage score and comparing it with the table below:

Percentage Score	Letter Grade	Percentage Score	Letter Grade
88-100	A	60-69	D
79-87	B	Below 60	F
70-78	C		

Attendance:

Regular class attendance is **strongly** recommended. You are responsible for all material discussed in class. It is in your best interest to *always* attend class and arrive on time - this class begins promptly at 1:00 pm!

Accommodation for Students with Physical and Learning Disabilities:

In coordination with Educational Access Services, reasonable accommodations will be provided for qualified students with disabilities. Students must register with the EAS office to receive assistance. Please meet with the instructor the first week of class for information and/or contact Dana VandeBurgt, the Coordinator of Educational Access Services, directly by phone at 248-1801, or in person in Houston Hall, Suite 108.

Academic Integrity:

All incidents of academic dishonesty, including, but not limited to, plagiarism and cheating, will be handled according to CMU policy. For CMU policy on academic integrity, please refer to 2018-2019 CMU Catalog, pp. 86.

Course Calendar:

This is a TENTATIVE course calendar ONLY! The actual course can (and most likely will) deviate from the calendar listed below.

Date	Subject
Wed, Jan 23	<i>Board of Trustees Meeting – No Class</i>
Fri, Jan 25	Ch.1 – Gravitational Physics / Ch. 2 – Geometry as Physics
Mon, Jan 28	Ch. 2 – Geometry as Physics
Wed, Jan 30	Ch. 3 – Space, Time, and Gravity in Newtonian Physics
Fri, Feb 1	Ch. 3 – Space, Time, and Gravity in Newtonian Physics
Mon, Feb 4	Ch. 4 – Principles of Special Relativity
Wed, Feb 6	Ch. 4 – Principles of Special Relativity
Fri, Feb 8	Ch. 4 – Principles of Special Relativity
Mon, Feb 11	Ch. 5 – Special Relativistic Mechanics
Wed, Feb 13	Ch. 5 – Special Relativistic Mechanics
Fri, Feb 15	Ch. 5 – Special Relativistic Mechanics
Mon, Feb 18	Exam 1 (Chapters 1 - 4)
Wed, Feb 20	Ch. 6 – Gravity as Geometry
Fri, Feb 22	Ch. 6 – Gravity as Geometry
Mon, Feb 25	Ch. 6 – Gravity as Geometry
Wed, Feb 27	Ch. 7 – The Description of Curved Spacetime
Fri, Mar 1	Ch. 7 – The Description of Curved Spacetime
Mon, Mar 4	Ch. 7 – The Description of Curved Spacetime
Wed, Mar 6	Ch. 7 – The Description of Curved Spacetime
Fri, Mar 8	Ch. 7 – The Description of Curved Spacetime
Mon, Mar 11	Ch. 7 – The Description of Curved Spacetime
Wed, Mar 13	Ch. 8 – Geodesics
Fri, Mar 15	Ch. 8 – Geodesics
Mon, Mar 18	<i>Spring Break – No Classes</i>
Wed, Mar 20	<i>Spring Break – No Classes</i>
Fri, Mar 22	<i>Spring Break – No Classes</i>
Mon, Mar 25	Ch. 8 – Geodesics
Wed, Mar 27	Ch. 9 – The Geometry Outside a Spherical Star
Fri, Mar 29	Exam 2 (Chapters 5 - 7)
Mon, Apr 1	Ch. 9 – The Geometry Outside a Spherical Star
Wed, Apr 3	Ch. 9 – The Geometry Outside a Spherical Star
Fri, Apr 5	Ch. 9 – The Geometry Outside a Spherical Star
Mon, April 8	Ch. 9 – The Geometry Outside a Spherical Star /Ch. 12 –

	Gravitational Collapse and Black Holes
Wed, April 10	Ch. 12 – Gravitational Collapse and Black Holes
Fri, April 12	Ch. 12 – Gravitational Collapse and Black Holes
Mon, April 15	Ch. 12 – Gravitational Collapse and Black Holes
Wed, April 17	Ch. 12 – Gravitational Collapse and Black Holes
Fri, April 19	<i>Board of Trustees Meeting/Student Showcase – No Class</i>
Mon, April 22	Exam 3 (Chapters 8, 9 & 12)
Wed, April 24	Ch. 17 – The Universe Observed
Fri, April 26	Ch. 17 – The Universe Observed
Mon, April 29	Ch. 17 – The Universe Observed
Wed, May 1	Ch. 18 – Cosmological Models
Fri, May 3	Ch. 18 – Cosmological Models
Mon, May 6	Ch. 18 – Cosmological Models
Wed, May 8	Ch. 18 – Cosmological Models
Fri, May 10	Exam 4 (Chapters 17 & 18)

****Final Exam:** Wednesday, May 15 at 1 - 2:50 pm**